

FOSSILS, THEIR USES AND GEOLOGIC TIME

PREPARED TO MEET SOUTH
CAROLINA SCIENCE
STANDARDS FOR THE 8TH
GRADE:

STANDARD II, 4a,b,c,d,and e
and 5a, b, and c.

FOSSILS

A fossil is any evidence of a once-living organism. This includes body parts, casts, molds, footprints, track ways and feeding traces. This evidence of previous living organisms can then be used to study changes in life forms through time. This includes their evolution, ecology, functional morphology, growth, and form, as well as their geographic distribution. Fossils provide us with our best link to the history of life. The vast majority of fossils are found in sedimentary rocks.

USE OF FOSSILS

- They are direct records of ancient life and illustrate the development or "evolution" of life through time.
- They are important indicators of past environments.
- They can be useful for correlation of strata because they have restricted geologic age ranges.

INDEX FOSSIL

- An **index fossil** is an abundant and easily identifiable fossil with a wide geographic distribution and a short **geologic range**. The geologic range of a fossil is the span of geologic time between the organism's appearance and its disappearance in the geologic record. Index fossils, also known as guide fossils, are used by geologists to determine the relative ages of strata and to correlate rock units.

USING FOSSIL ASSEMBLAGES TO DETERMINE THE RELATIVE AGES OF ROCK UNITS

Most organisms' geologic ranges are relatively long, covering multiple geologic periods; therefore, an individual fossil may not be very helpful in determining the relative age of the rock. The geologic ranges of the various species may vary greatly, but all of the members of the **fossil assemblage** are assumed to have been living during the same period of geologic time. If all the fossils were collected from the same rock unit, representing the same interval of sedimentary deposition, then all of the organisms were buried during that interval. By determining the period(s) during which the geologic ranges of the fossils overlap, one can ascertain when the sediments containing the fossils were deposited. In this case, the only period during which all the fossils lived was the Permian.

	FOSSILS							
<u>GEOLGIC PERIOD</u>	A	B	C	D	E	F	G	H
Quarternary								
Tertiary								
Cretaceous		X		X			X	
Jurassic		X		X		X	X	
Triassic	X	X	X	X		X	X	
Permian	X	X	X	X	X	X	X	X
Pennsylvanian	X		X	X	X	X	X	X
Mississippian	X			X	X			X
Devonian					X			X
Silurian								X
Ordovician								X
Cambrian								X

FOSSILIZATION

- There are several ways that organisms can be preserved as fossils. It is important to note, however, that the vast majority of organisms will not end up being preserved. Conditions do not typically favor fossilization, and the fossil record represents only a tiny fraction of all the individual organisms that have ever lived on Earth. There are a couple of factors that determine whether an organism will end up being fossilized. First, an organism's hard parts (bone, shell, etc.) are more likely to be preserved than soft tissues that will decay or be consumed by scavengers. Because of this, organisms possessing hard parts are more likely to be preserved than soft-bodied creatures (like jellyfish). Also, the more rapidly the remains are buried by sediment, the more likely they will survive to be fossilized. Rapid burial minimizes the decay, consumption, and destruction of the remains.

MODES OF PRESERVATION

Unaltered Remains--This category includes those fossils that have undergone little or no change in structure and composition. As a general rule (but by no means absolute), an organism that lived fairly recently has a greater probability of being unaltered than a more ancient one.

Altered Remains--As sediments become compressed by the weight of overlying sediments, they slowly undergo the process of lithification. Common cementing materials in the ground water are carbonate, silica, and iron oxides. Often the ground water and its minerals may affect the fossilization process.

Trace fossils--Preservation of signs of organic activity such as brings and burrows, coprolites, gastroliths, eggs, tooth marks, and footprints or track ways.

Molds and casts-- A mold is a negative impression of a fossils surface. A cast is a mold that has filled with sediment and is a replica of the original.

UNALTERED REMAINS

Original Skeletal Material--Organisms that have hard parts are preserved as the original material. This includes many invertebrate shells composed of calcium carbonate, silica, chitin, or vertebrate bones of calcium phosphate.

Encrustations--In many caves, ground water seeps and drips constantly. The high concentration of dissolved minerals in such water is left behind when the water drips, and if it forms a thin crust on the interior surface of the cave and whatever lies in it. This will coat and preserve any organism that dies here.

Tar Impregnation--Tar pits are excellent sites for fossilization. The famous Rancho La Brea tar pits in southern California have yielded particularly rich collections of vertebrate bones, wood, etc. Smaller pits have yielded perfectly preserved insects and even insect larvae.

Amber Entombment--Certain cone-bearing trees, such as spruce, pine, and fir, contain a sticky resinous "pitch" that comes from wounds in the tree. Small insects and other minute organism may become trapped in this resin, which after burial may harden into amber. Certain parts of the Baltic Sea coast and some of the islands in the West Indies are well known for occurrences of insects preserved in amber.

Refrigeration--During the Pleistocene glaciation, when ice sheets covered much of the Northern Hemisphere, some animals (mammoths, for example) fell into crevasses in frozen terrain or became trapped in permanently frozen soil. Some of these animals have been discovered perfectly preserved.

Mummification--In very arid regions, animals may dry out quickly and be preserved, soft parts and all. Anyone who has found a dried-out fish behind the tank has seen this type of preservation.

Unaltered Remains

- Original skeletal material: sharks teeth (calcium phosphate).



Unaltered Remains

- Mummification



Unaltered Remains

- Amber



Unaltered Remains

- Freezing: a frozen woolly mammoth



ALTERED REMAINS

Permineralization -- Many bones, shells, and plant stems have porous internal structures. These pores may become filled with mineral deposits. In the process of permineralization, the actual chemical composition of the original hard parts of the organism may not change.

Dissolution/Replacement -- Groundwater (especially acidic groundwater) may act to dissolve a hard structure in an organism trapped in sediments and may, simultaneously deposit a mineral in its place--molecule by molecule. Replication of tree trunks, including their internal microscopic cellular structure, by silica in the process of forming petrified wood is a classic example of this type of fossilization.

Recrystallization – conversion, essentially in the solid state, of the mineralogy of the fossil usually to a new mineral or to coarser crystals of the original mineral.

Carbonization -- When organisms become mashed into the sediment, their volatile (liquid or gaseous) components may be forced out, leaving only a film of carbon. If additional organic matter remains when, for example, plants are entombed, the result is coal.

Altered Remains

- Replacement: Water seeping through sedimentary rocks that contain fossil bones and shells may dissolve some of the hard parts and at the same time replace them with minerals that it carries in solution. The effect is to substitute another material for the original hard parts without changing the form of the shell or bone. In the photograph on the right the calcium carbonate shell of a brachiopod has been replaced by pyrite (iron sulfide).



Altered Remains

- Permineralization;
Mineral matter added
to pores and cavities
after burial. Makes
preservation more
likely by increasing
durability.



Altered Remains

- Carbonization: This is often how soft-bodied animals and plants are preserved. As the organism decays, the volatile components of the organic matter (oxygen, hydrogen, and nitrogen) are driven away, leaving behind a thin film of carbon.



TRACE FOSSILS

Borings and Burrows--Certain worms and clams and many other invertebrates burrow into rocks, wood, shells, and all types of sediment. These burrows are frequently preserved, especially in fine-grained rocks.

Coprolites--Fossil excrement can sometimes give definitive knowledge about the diet of the animal concerned.

Gastroliths--These are smooth, polished stones that are often found in the abdominal cavities of the skeletons of dinosaurs. They are thought to have helped those huge animals grind up vegetable matter in their stomachs.

Gnawings--Rodents and other animals chew on bones for the calcium content as they did in the past. Gnawed bones are frequently preserved as fossils.

Footprints and track ways-- Impressions the footprints of vertebrate organisms or trails of invertebrate organisms.

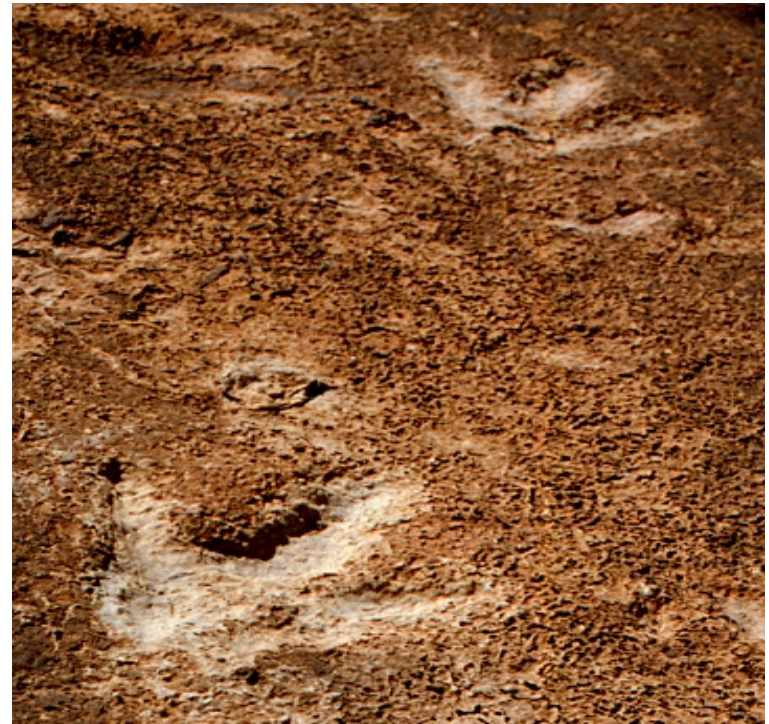
Trace Fossil

- Burrow



Trace Fossil

- Footprints or track ways



Trace Fossil

- Coprolites are fossilized feces of animals.



Trace Fossil

- Gastroliths are smooth stones that aided in the breakdown of plant material in the animal's stomach.



Trace Fossil

- Tooth marks left on bone by carnivores.



Trace Fossil

- Dinosaur eggs or nests



MOLDS AND CASTS

- Instead of replacing a fossil shell, water passing through the sediment may dissolve the shell away completely and if the rock surrounding the shell has lithified, a void will be formed. These impressions are called molds; as an example, knobs or spines on a shell are represented by depressions in the rock. A mold is a negative impression of its surfaces. Sometimes the void is filled later by a mineral deposit that has the shape of the external form, but no internal structure. This is a cast or a replica of the original.

MOLD

- A mold is a negative impression of its surfaces.



INTERNAL MOLD

- Internal molds occur where the original material has dissolved away the sediment has filled the internal portion of the animal leaving, a replica of the inside of the animal



TIME

- **Relative time** ("chronostratic") -- subdivisions of the Earth's geology in a specific order based upon relative relationships (most commonly, vertical/stratigraphic position). These subdivisions are given names, most of which can be recognized globally, usually on the basis of fossils.
- **Absolute time** ("chronometric") -- numerical ages in "millions of years" or some other increment of time. These are most commonly obtained via radiometric dating methods performed on appropriate rock types.
 - Think of relative time as physical subdivisions of the rock found in the Earth's stratigraphy and absolute-time as the measurements taken to determine the actual time that has passed. Absolute-time measurements can be used to calibrate the relative-time scale, producing an integrated geologic or "geochronologic" time scale.

RELATIVE TIME

- Relative time tells of the sequence of the way events occurred and not the exact time these events took place. The following list is placed in relative order.
 - I woke up this morning
 - I ate breakfast
 - I brushed my teeth.
 - I took a shower.
 - I got dressed.
 - I left for school

ABSOLUTE TIME

- Absolute time tells the exact time an event occurred.
- I was born in 19__
- I started to walk 19__
- I started kindergarten 19__
- I started 6th grade 19__

RELATIVE DATING METHODS

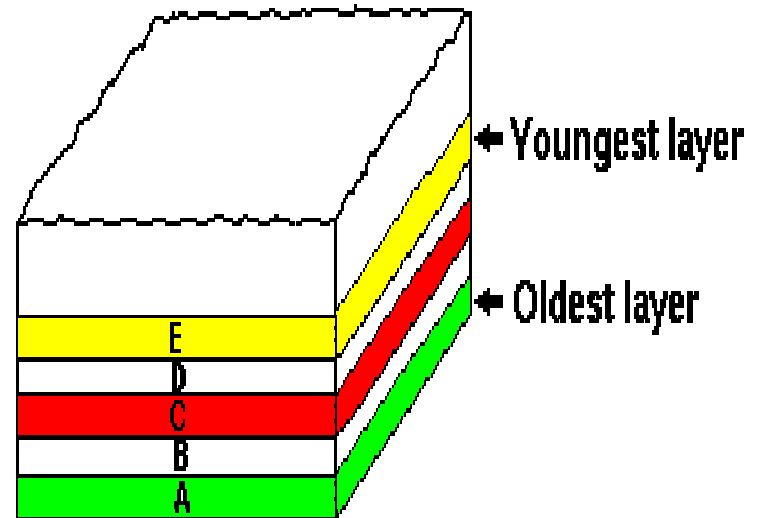
- UNIFORMITARIANISM
- SUPERPOSITION
- ORIGINAL HORIZONTALITY
- LATERAL CONTINUITY
- CROSS-CUTTING RELATIONSHIPS
- INTRUSIVE RELATIONSHIPS
- UNCONFORMITIES
- INCLUSIONS
- CORRELATION

UNIFORMITARIANISM

- Idea by James Hutton in *Theory of the Earth* (1793). The physical, chemical, and biological laws that operate today have operated throughout geologic time. Thus, the forces and processes that we observe presently shaping our planet have been at work since the planet's creation. "The present is the key to the past." This important concept can be applied to relative time and absolute time.

SUPERPOSITION

- The **principle of superposition** states that older beds are covered by younger beds, so that in a sedimentary sequence the youngest unit is at the top.



ORIGINAL HORIZONTALITY

- Sedimentary rocks were originally deposited in horizontal beds. Sedimentary rocks that are not horizontal have been affected by some tectonic process.



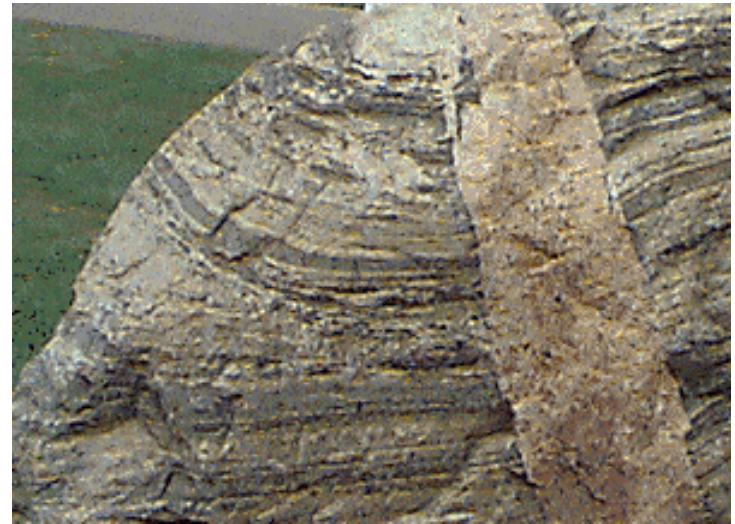
CROSS-CUTTING RELATIONSHIPS

- Faults are younger than the rocks they cut through. In the figure to the right the fault is younger than the cinder cone.



INTRUSIVE RELATIONSHIPS

- Invading igneous intrusions are always younger than the rock they intrude.



UNCONFORMITIES

- A surface of nondeposition or erosion encompassing significant amounts of geologic time. Recognizing unconformities in the geologic record is important in correlation and in determining relative age. There are three types of unconformities.

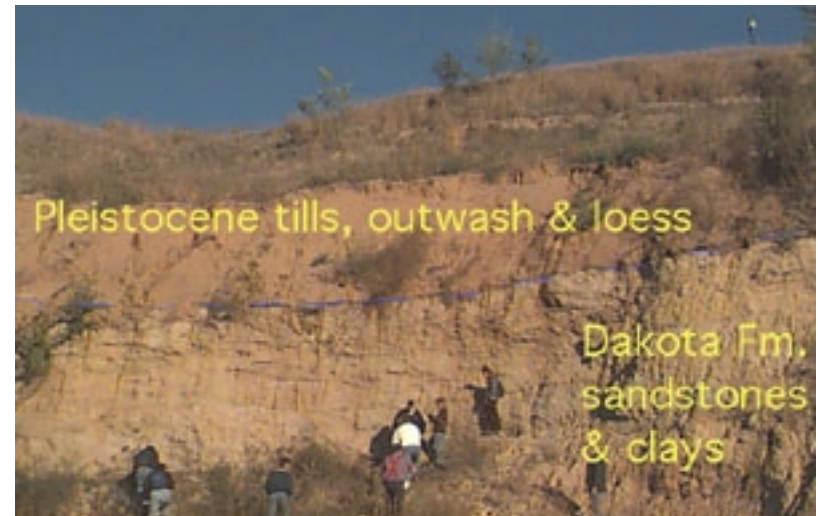
Angular unconformity

- Angular unconformity: the beds below the unconformity dip at a different angle from the beds above it.



Nonconformity

- Nonconformity: the beds above and below are parallel.



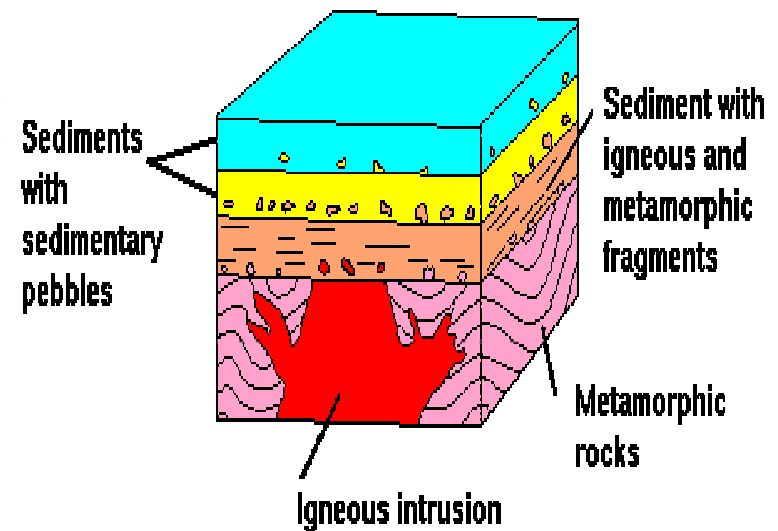
Disconformity

- A disconformity separates profoundly different rock types, such as sedimentary rocks from metamorphic rocks in the photograph on the right.



INCLUSIONS

- Any included pebbles and fragments must be older than the host rock containing them.

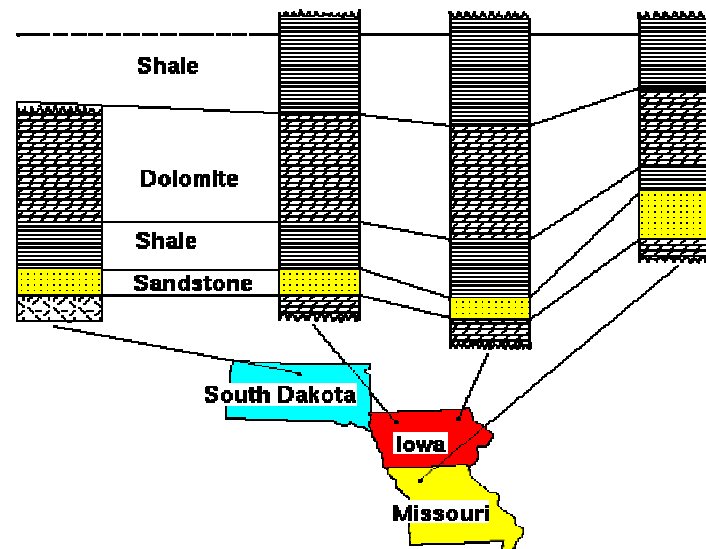


CORRELATION

- The method of using similarities between geologic units to extend information about geologic sequences over large geographic areas.

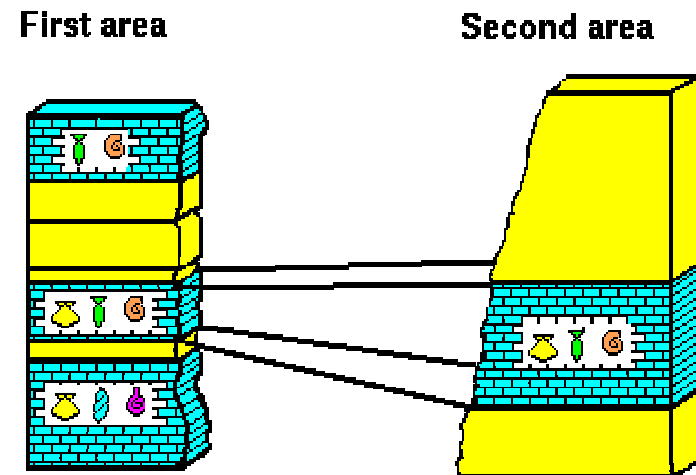
Lithologic correlation

- In lithologic correlation, a unit is recognized by its lithology (rock type) or a sequence of lithologies. The same distinctive sequence of sandstone (oldest), shale, dolomite, shale (youngest) is recognized over much of the north-central United States.

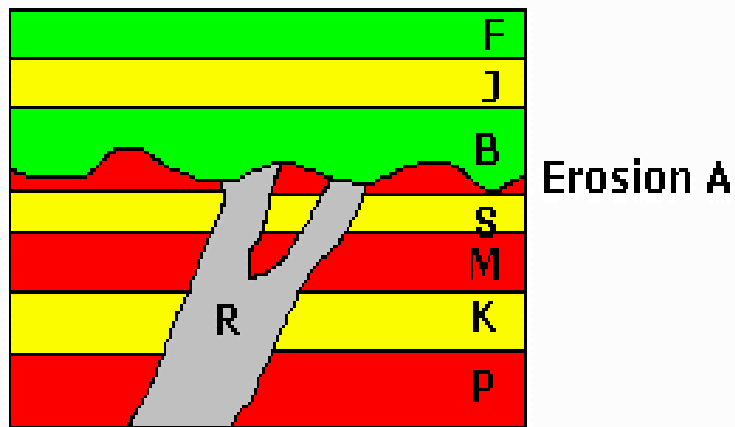


Fossil succession

- The principle of fossil succession states that organisms evolve through time, and, therefore, particular forms can be used as age markers wherever they are found. The kinds of animals and plants found as fossils change through time. When we find the same kinds of fossils in rocks from different places, we assume that the rocks are the same age.



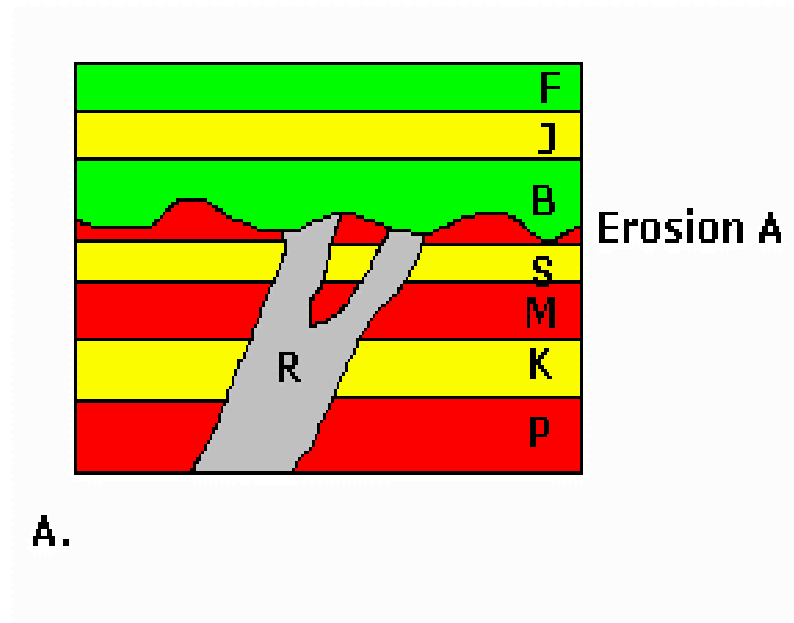
UNRAVELING RELATIVE TIME



A.

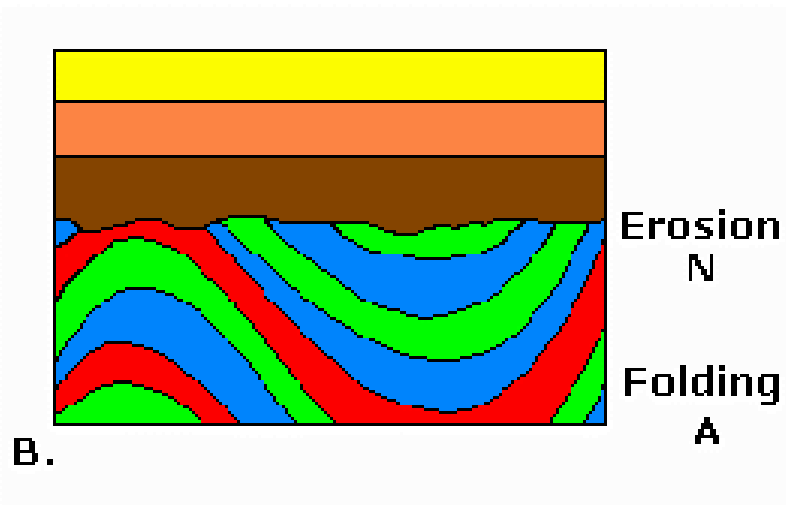
- Explain the sequence of events in the cross-section on the left.

UNRAVELING RELATIVE TIME



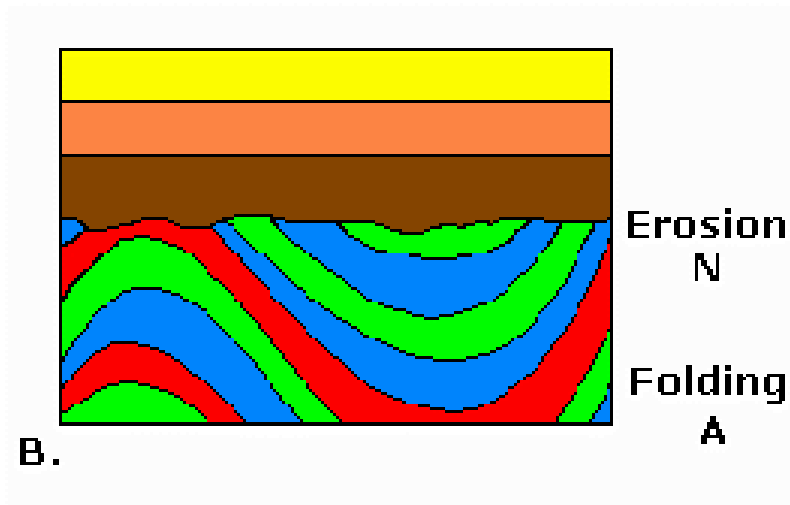
- 1. Beds P, K, M, and S deposited
- 2. Intrusion of R
- 3. Erosion of surface A
- 4. Subsidence and deposition of beds B, J, F

UNRAVELING RELATIVE TIME



- Explain the sequence of events in the cross-section on the left.

UNRAVELING RELATIVE TIME



- 1. Deposition of blue, green and red beds.
- 2. Folding A
- 3. Uplift and erosion of N
- 4. Subsidence and deposition of brown, flesh, and yellow beds

ABSOLUTE TIME

- Like a clock, absolute dating tells us when a geological event occurred. It provides evidence that the Earth is 4.6 billion years old. Measuring techniques rely on looking at geological processes with a strong annual signature (e.g. growth rings in various organisms) or at processes that occur at a constant and measurable rate (e.g. radioactive decay).

ABSOLUTE-DATING TECHNIQUES

- **Radioactive dating**
- **Tree rings**
- **Varves**

EARLY ATTEMPTS AT DETERMINING THE AGE OF THE EARTH

Biblical methods extrapolating age by using generations listed in Genesis

John Lightfoot (1644)

Bishop James Ussher (1665)

Salt concentration in the oceans

John Joly (1899), 90 million years

Rates of deposition

John Phillips (1860), 96 Million years

C.D Walcott (1893), 27.6 Million years

Heat flow from the earth

Lord Kelvin (1862), 20 to 40 million years

RADIOACTIVE DATING

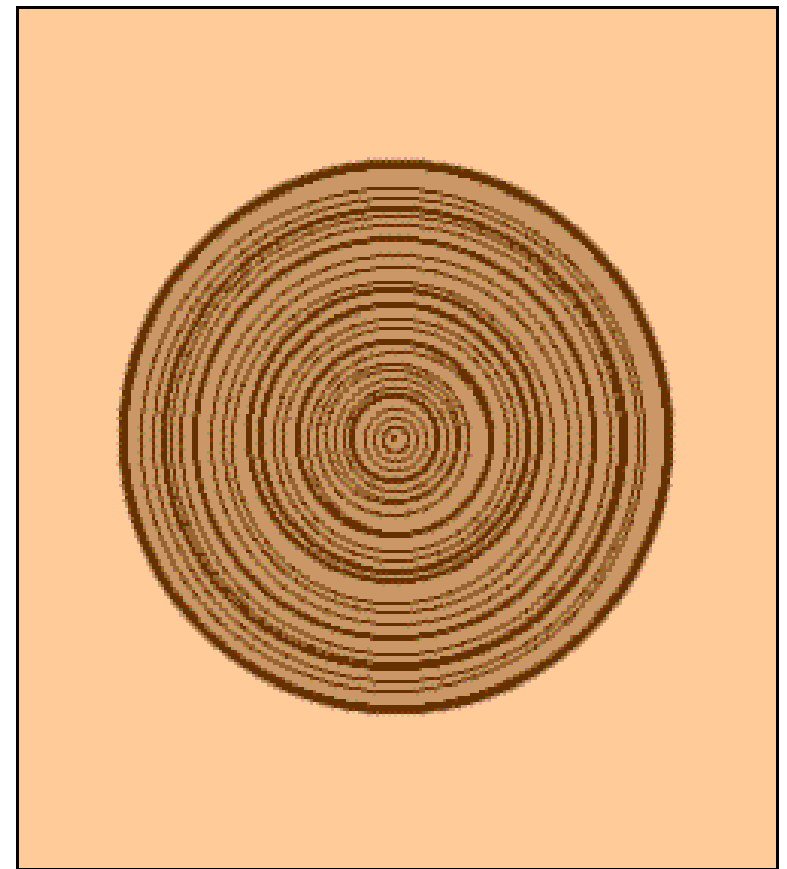
- Radioactive elements decay (fall apart) at steady rates. One "half-life" of time has passed when exactly half of the element remains. Half lives differ from element to element. When they fall apart they form a different material. A ratio between the original material (parent material) and the decay product (daughter material) can be used to determine how many half-lives the material has undergone. The chart on the right illustrates some important radioactive elements used in dating rocks.

Isotope		Half-life of parent (years)	Useful range (years)
Parent	Daughter		
Carbon 14	Nitrogen 14	5,730	100 - 30,000
Potassium 40	Argon 40	1.3 billion	100,000 - 4.5 billion
Rubidium 87	Strontium 87	47 billion	10 million - 4.5 billion
Uranium 238	Lead 206	4.5 billion	10 million - 4.6 billion
Uranium 235	Lead 207	710 million	

TREE RINGS

(DENDROCHRONOLOGY)

- Dendrochronology is another traditional technique for establishing the absolute date of events. This is also called Tree-Ring Dating. Tree-Ring dating is based on the principle that the growth rings of certain species of trees reflect variations in seasonal and annual rainfall. Trees from the same species, growing in the same area or environment will be exposed to the same conditions, and hence their growth rings will match at the point where their life cycles overlap.



VARVES

- Sections cut through lake beds in glacial regions reveal a regular annual pattern of coarse (sand/silt) and fine (clay) layers, known as varves. Varves allowed the end of the last Ice Age to be dated with confidence to around 6800 BC and provided the first extension of 'calendar' dates into European prehistory.



THE GEOLOGIC TIME SCALE

Long before geologists had the means to recognize and express time in numbers of years before the present, they developed the geologic time scale. This time scale was developed gradually, mostly in Europe, over the eighteenth and nineteenth centuries. The geologic time scale provides a relative measure of time and is based on the fossil record. Fossil species appear and disappear throughout the stratigraphic record. The Geologic Time Scale is based on these appearances and disappearances. Each of the Eras ends with a mass extinction. Period boundaries coincide with smaller extinction events, followed by appearance of new species.

DIVISIONS OF GEOLOGIC TIME

Eons: longest time spans

Eras: subdivision of Eons on the basis of life forms

Periods: subdivision of Eras, also on the basis on life forms

Epochs: further subdivision of Periods, on the basis of life forms

THE GEOLOGIC TIME CHART

EON	ERA	PERIOD	EPOCH
Phanerozoic	Cenozoic	Quaternary	Holocene Pleistocene
		Tertiary	Pliocene Miocene Oligocene Eocene Paleocene
	Mesozoic	Cretaceous	Late Early
		Jurassic	Late Middle Early
		Triassic	Late Early
	Paleozoic	Permian	Late Early
		Pennsylvanian	Late Middle Early
		Mississippian	Late Early
		Devonian	Late Middle Early
		Silurian	Late Middle Early
		Ordovician	Late Middle Early
		Cambrian	Late Middle Early
Proterozoic	Late Proterozoic Middle Proterozoic Early Proterozoic		
Archean	Late Archean Middle Archean Early Archean		
pre-Archean			

Relative time

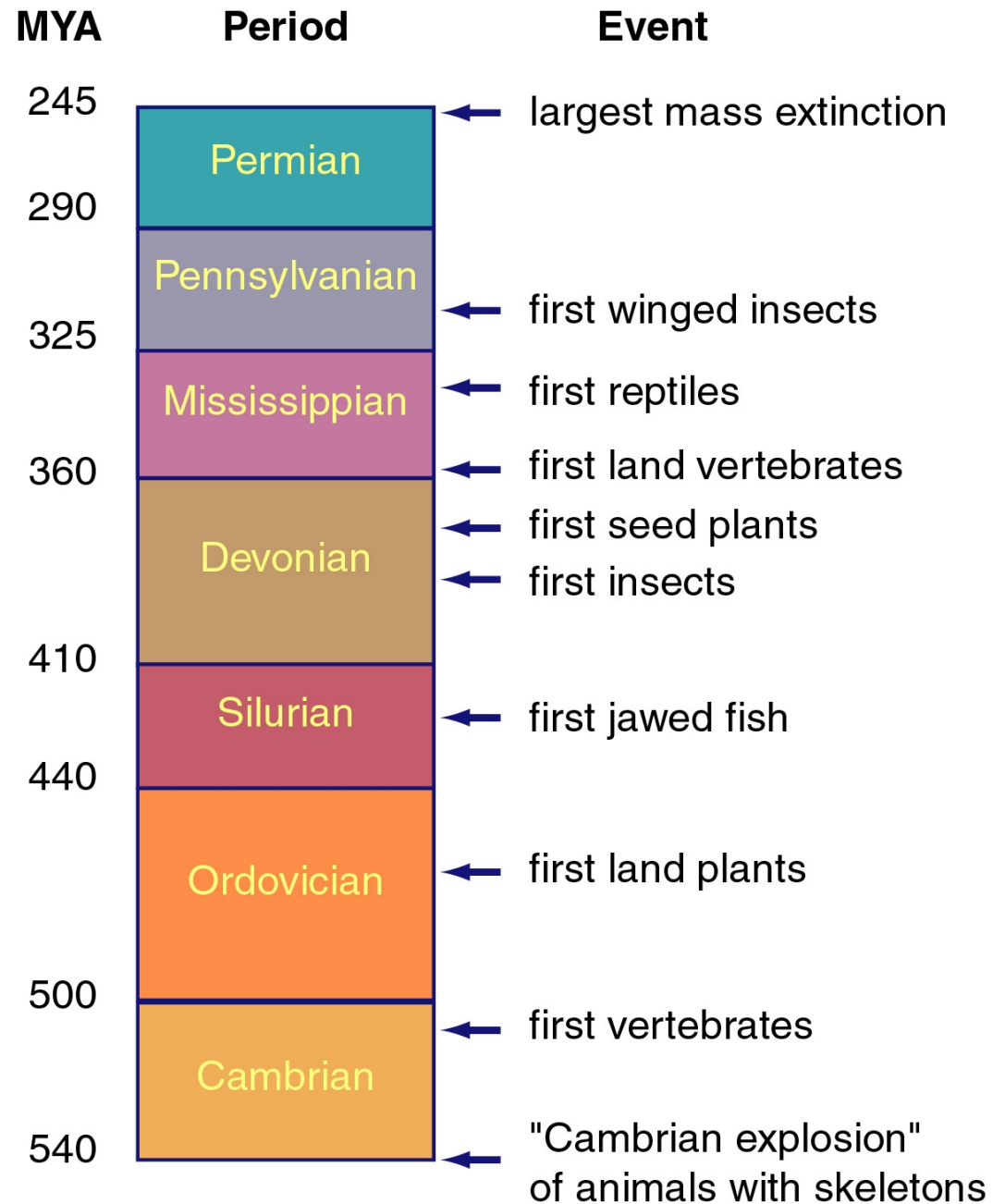
Cenozoic	Quaternary	2
	Tertiary	66
Mesozoic	Cretaceous	144
	Jurassic	208
	Triassic	248
Paleozoic	Permian	286
	Pennsylvanian	320
	Mississippian	360
	Devonian	408
	Silurian	438
	Ordovician	510
	Cambrian	543
Proterozoic	Yendian	563
Archean	Precambrian	4.6 billion

Absolute time

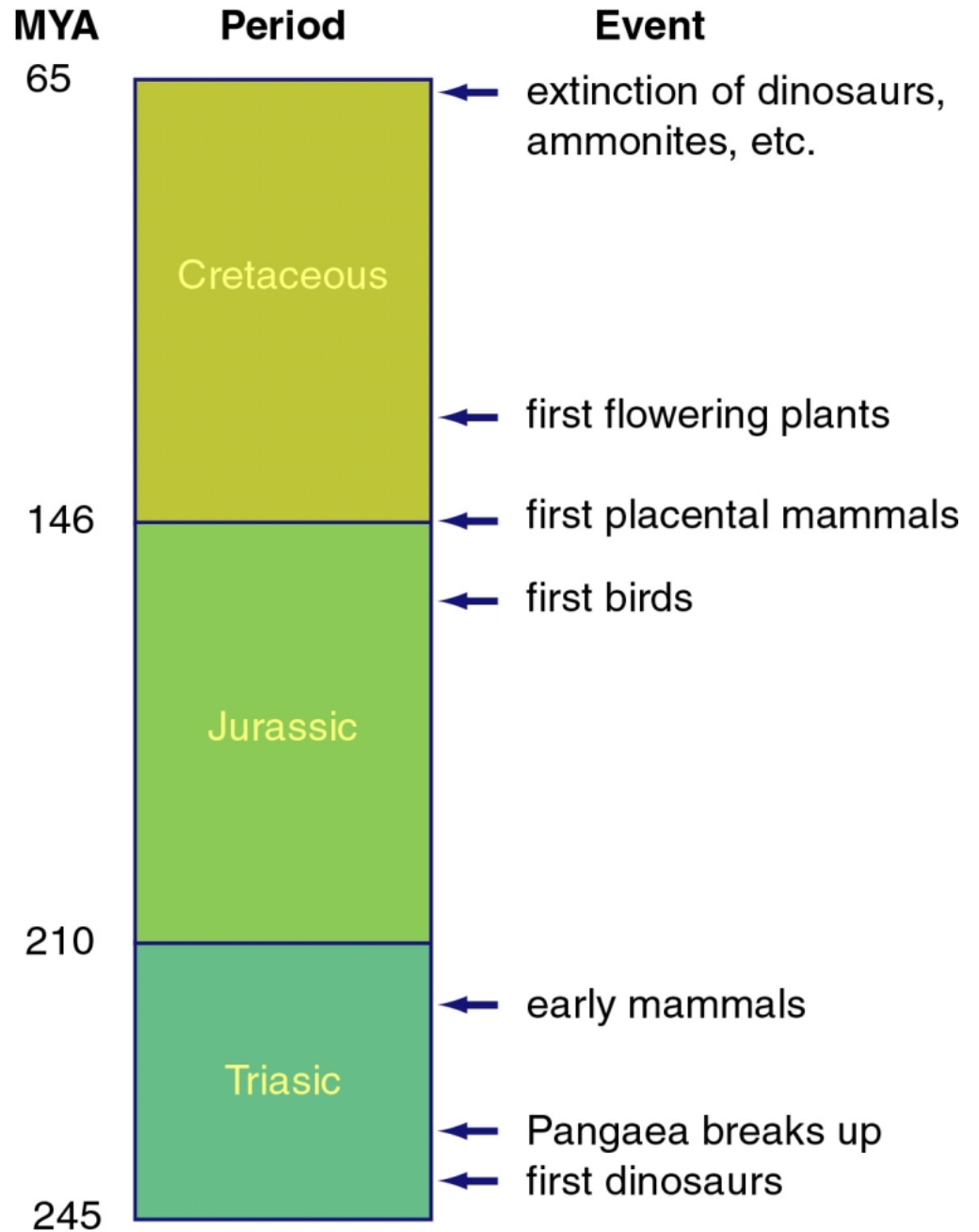
STRATIGRAPHIC RANGES OF SOME MAJOR GROUPS OF ANIMALS AND PLANTS

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Paleozoic Events



Mesozoic Events



Cenozoic Events

